M 313/990

ANNUAL REPORT

MANGANESE

By Thomas S. Jones

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

READEX MICRO best copy available

I 28.37/a:

ANNUAL REPORT

MANGANESE

U.S.
DEPARTMENT
OF THE
INTERIOR

Manuel Lujan, Jr.
Secretary

BUREAU
OF
MINES

T S Ary
Director

September 1991

Contents

Domestic Data Coverage 1
Background 1
Definitions, Grades, and Specifications 1
Ore 1
Ferroalloys and Metal 2
Products for Trade and Industry 2
Industry Structure 2
Geology-Resources 2
Technology 2
Exploration 2
Mining 2
Beneficiation 3
Processing 3
Recycling 3
Economic Factors 3
Operating Factors 3
Environmental Requirements 3
Toxicity 3
Annual Review 3
Legislation and Government Programs 3
Strategic Considerations 3
Security of Supply 3
Stockpile 3
Issues 4
Production 4
Ore and Concentrate 4
Ferroalloys, Metal, and Synthetic Dioxide 4
Consumption, Uses, and Stocks 4
Markets and Prices 5
Manganese Ore 5
Manganese Ferroalloys 5
Manganese Metal 7
Foreign Trade 7
World Review 7
Capacity 7
Reserves 7
Australia 7
Brazil 10
Bulgaria 11
Canada 11
Gabon 11
Ghana 11
India 12
Japan 12
Mexico 12
South Africa, Republic of 12
U.S.S.R. 12
Current Research 13
Outlook 14

Tables

Table 1.—Salient Manganese Statistics 1
Table 2.—U.S. Government Stockpile Goals and Yearend Inventories for Manganese Materials in 1990 4
Table 3.—Sales and Inventory Changes for Manganese Materials in U.S. Government Stockpile, 1990 4
Table 4.—Domestic Producers of Manganese Products in 1990 5
Table 5.—U.S. Consumption and Industry Stocks of Manganese Ore, by Use 5
Table 6.—U.S. Consumption, by End Use, and Industry Stocks of Manganese Ferroalloys and Metal in 1990 6
Table 7.—U.S. Unit Consumption of Manganese in Ironmaking and Steelmaking 6
Table 8.—Time-Price Relationships for Manganese in Metallurgical Ore 6
Table 9.—U.S. Exports of Manganese Ore, Ferroalloys, and Metal, by Country 7
Table 10.—U.S. Imports for Consumption of Manganese Ore, Ferroalloys, Metal, and Selected Chemicals, by Country 8
Table 11.—U.S. Import Duties on Manganese Materials 10
Table 12.—World Annual Manganese Mine Production Capacity, December 31, 1990 11
Table 13.—World Manganese Reserves and Reserve Base 11
Table 14.—South African Manganese Ore Production, 1990 12
Table 15.—Manganese Ore: World Production, by Country 13
Table 16.—Manganese Supply-Demand Relationships 14

COVER PHOTO
Cell room used to produce electrolytic manganese dioxide, a key ingredient in alkaline dry cell batteries. (Photos are courtesy of Chemetals Inc. and Kerr-McGee Chemical Corp.)

For comments or further information, please contact
The Branch of Metals
The Division of Mineral Commodities
U.S. Bureau of Mines
2401 E St., NW, MS 5208
Washington, DC 20241-0001
Telephone: (202) 634-7091
Fax: (202) 634-6016

MANGANESE

By Thomas S. Jones

Dr. Jones, a physical scientist with 32 years of industry and U.S. Bureau of Mines experience, has been the commodity specialist for manganese since 1982. Domestic survey data were prepared by Glenn Wallace, mineral data assistant; and the international data table was prepared by William Zajac, Chief, Section of International Data.

Manganese is essential to iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties. Currently, no practical approaches exist for replacing it with other materials or for obtaining the bulk of U.S. requirements from domestic sources. Strategic concerns of the United States for manganese largely apply also to Japan and Western Europe.

In 1990, ironmaking and steelmaking continued to account for about 90% of domestic manganese demand. Unit consumption rates for manganese were lower in ironmaking and higher in steelmaking than in 1989. Government inventories of manganese, all forms, still represented more than 2 years of apparent consumption. As reflected by the data in table 1, U.S. imports of key manganese materials decreased overall compared with those of 1989. Imports of ore were the least since 1984.

For the third consecutive year, the actual price of metallurgical-grade manganese ore rose substantially to a new record high. This increase was stimulating development of modest amounts of additional ore production in Australia and Canada. Major producers were yet to carry out any significant expansions in output capability.

The level and nature of manganese use by the United States is not expected to change significantly in the near future, but the level will be subject to fluctuations in domestic and global steel production. Political and economic developments have made uncertain the U.S.S.R.'s future status as a major ore producer and supplier of ore to Eastern Europe.

TABLE 1

SALIENT MANGANESE STATISTICS

(Thousand short tons, gross weight)

	1986	1987	1988	1989	1990
United States:					
Manganese ore (35% or more Mn):					
Exports	42	63	68	57	77
Imports for consumption	463	341	512	639	338
Consumption	r500	r533	r554	616	548
Stocks, Dec. 31: Consumers	r455	r456	r458	518	418
Ferromanganese:					
Exports	4	3	3	9	8
Imports for consumption	396	368	531	476	419
Consumption	376	409	468	440	455
Stocks, Dec. 31: Consumers and producers	93	48	91	75	62
World:					
Production of manganese ore	r27,523	r26,006	r26,817	r27,626	e27,192

e Estimated. r Revised.

DOMESTIC DATA COVERAGE

Data on domestic consumption of manganese ore, exclusive of that consumed within the steel industry, are collected by means of the "Manganese Ore and Products" survey. The approximately 20 firms canvassed by means of this survey process ore by such methods as grinding and roasting or consume it in the manufacture of manganese ferroalloys, metal, and chemicals. In 1990, responses were obtained from all firms canvassed, whose collective consumption is believed to represent that of the United States except for negligible quantities consumed by other firms, if any. The aggregated consumption data so obtained were incorporated into table 5 but only displayed within totals to avoid disclosing proprietary data.

BACKGROUND

Definitions, Grades, and Specifications

Ore.—The U.S. Bureau of Mines has compiled statistics on manganese-bearing ores, concentrates, nodules, and sinter, all referred to simply as "ore," by manganese content as follows: **manganese ore,** 35% or more manganese; **manganiferous ore,** less than 35% but not less than 5% manganese; and within the latter **ferruginous manganese ore,** 10% to 35% manganese; and **manganiferous iron ore,** 5% to 10% manganese.

Manganese ore may be considered as metallurgical, chemical, or battery grade. Metallurgical-grade material has an approximate manganese content range of 38% to 55% and may differ from chemical-grade ore only in physical form. Chemical- and battery-grade ores are often categorized by manganese dioxide (MnO_2) content, which typically is in the range of 70% to 85% (44% to 54% Mn). The U.S. Govern-

ment maintains specifications for metallurgical, chemical, and battery grades of ore for stockpile purposes; industry has no corresponding standards.

Ferroalloys and Metal.—Ferromanganese is a manganese-iron-carbon alloy classified according to decreasing carbon content into standard or high-carbon grades, medium-carbon grades, and low-carbon grades. Silicon is also specified in silicomanganese (such as 18%) and ferromanganese-silicon (about 30%). For U.S. tariff purposes, ferroalloys are required to have an iron content of 4% or greater; a manganese material with less iron would be treated as manganese metal. The specifications the U.S. industry generally follows for manganese ferroalloys and metal are those of the American Society for Testing and Materials.

Products for Trade and Industry

Metallurgical-grade ore is used primarily in making ferroalloys, pig iron, and steel. In making ferroalloys, ore with a relatively high manganese and low phosphorus content is particularly desirable.

The sulfur-fixing, deoxidizing, and alloying attributes of manganese are obtained mostly through use of intermediate forms such as ferromanganese. Manganese ferroalloys for use in steelmaking are selected on the basis of cost per manganese unit, allowable steel carbon and silicon specifications, and steelmaking practice. For 1990, with the cost of manganese in metallurgical ore taken as 1.0, the corresponding approximate costs per manganese unit were 2.2 for high-carbon ferromanganese, 1.7 for silicomanganese, 3.3 for medium-carbon ferromanganese, and 5.5 for manganese metal. Metallic manganese is little used per se because it is typically brittle and unworkable.

Manganese is added to aluminum using aluminum-manganese master alloys that typically contain 25% Mn, briquets of compacted aluminum and manganese powders that typically contain 75% Mn, and electrolytic manganese metal.

Various manganese dioxide-types of material, possibly ground, are used for batteries and other applications. These include natural mineral product (NMD) and synthetic dioxide produced either electrolytically (EMD) or chemically (CMD).

Other manganese materials and some of their uses include manganese sulfate and manganous oxide (MnO) for animal feed and soil conditioners, ground manganese ore for brick coloring, and potassium permanganate for water treatment.

Industry Structure

Makeup of the world's manganese ore producers is chiefly as follows: Australia, Groote Eylandt Mining Co. Pty. Ltd. (GEMCO); Brazil, Cia. Vale do Rio Doce (CVRD) and Indústria e Comércia de Minérios S.A. (ICOMI), plus a number of relatively small mines; China, apparently mostly small- to moderate-size operations in the eastern Provinces; Gabon, Compagnie Minière de l'Ogooué S.A. (COMILOG); Ghana, Ghana National Manganese Corp.; India, more than 200 mines, with Manganese Ore India Ltd. the most prominent company; Mexico, Cía. Minera Autlán de C.V. (Autlán); Republic of South Africa, The Associated Manganese Mines of South Africa Ltd. (AMMOSAL) and Samancor Ltd.; and the U.S.S.R., two large complexes, mining the Chiatura Basin in Georgia and the Nikopol' Basin in the Ukraine. Most ore produced goes into metallurgical applications.[1] Ore for nonmetallurgical uses generally is supplied by the large-scale producers mentioned plus smaller ones elsewhere.[2]

In recent years, the U.S.S.R. has been supplying more than 1 million tons[3] of ore annually to Eastern Europe. Such exports were notably lower in 1987 and appear likely to decline considerably in the future. Otherwise, the principal source of ore to the international market has been an oligopolistic-like group of countries consisting of Australia (GEMCO), Brazil (ICOMI and CVRD), Gabon (COMILOG), and the Republic of South Africa (AMMOSAL and Samancor).

Smelting of ore into manganese ferroalloys is much more diversified than ore production. Leading ferroalloy producers are as follows: Brazil, Cia. Paulista de Ferro-Ligas (a number of plants); China, many plants; France, Société du Ferromanganèse de Paris-Outreau (SFPO); Federal Republic of Germany, Thyssen Stahl AG; Japan, Japan Metals & Chemicals Co. Ltd. and Mizushima Ferroalloy Co. Ltd.; Mexico, Autlán; Norway, Elkem A/S; Republic of South Africa, Metalloys Ltd., a subsidiary of Samancor; and the U.S.S.R., a number of plants. The U.S.S.R. is by far the largest producer.

Four market economy countries (MEC's) currently produce metal, all electrolytically, in decreasing order of capacity: the Republic of South Africa, the United States, Japan, and, beginning in 1989, Brazil. China and the U.S.S.R. produce metal, including that produced metallothermically in the U.S.S.R. World productive capacity for metal was given as 84,000 tons annually as of 1985,[4] and would be approximately the same in 1990.

Annual world capacity for EMD was assessed as 218,000 tons in 1989, including capacities of 78,000 tons for Japan and 39,000 tons for the United States.[5] The principal producer of CMD is Belgium's Sedema S.A., with annual capacity of about 40,000 tons.

Geology-Resources

The world's major land-based economic resources of manganese are of two principal types: marine chemical sediments and secondary enrichment deposits.[6] Marine chemical deposits represent a majority of known resources. In 1985, the Manganese Centre (name changed in 1989 to International Manganese Institute) estimated that known relatively high-grade deposits (those with a manganese content of at least 44%) contained about 360 million tons of manganese.[7] As given in the "World Review" section of this chapter, the reserve base for manganese can be considered more than 10 times this size. The world's potential supply of manganese also includes extensive marine accumulations, such as oxide nodules on deep ocean floors and oxide crusts on midocean ridges, whose commercial future is indeterminate. Among the more common minerals occurring in manganese ores are oxides, including pyrolusite, a mineral form of manganese dioxide; the oxysilicate braunite; and rhodochrosite, a mineral manganese carbonate.

Technology

Exploration.—Highly selective methods of locating land manganese deposits do not exist, but interpretation of geologic environments can assist prospecting.[8]

Mining.—Most manganese ore is produced by mechanized operations. Stan-

dard earth-moving equipment is used in surface mining. Underground mining generally is by room-and-pillar techniques. Selective mining may be practiced in producing battery- and chemical-grade ores from a deposit being worked principally for metallurgical-grade ore.

Beneficiation.—Crushing, screening, washing, jigging, and tabling as well as flotation, heavy-medium, and high-intensity magnetic separation are being or have been used to upgrade raw manganese ore into usable concentrates. Carbonate ore may be calcined. Ore fines are sintered into bulkier shapes at some ferroalloy plants, a practice being adopted increasingly by ore producers as well.

Processing.—Electrothermy is the predominant method of manufacturing manganese ferroalloys, as by the submerged-arc-furnace process.[9] Blast furnace-type operations are still used in a few foreign countries to make important quantities of high-carbon ferromanganese. Recovery of metallics other than iron from manganese-bearing ore is rare.

Manganese metal and EMD commonly are produced by electrolyzing a solution of manganese sulfate prepared from ore that has been reduction roasted. Production of the dioxide is especially sensitive to minor ore impurities.[10] Chemical manganese dioxide can be prepared by precipitating manganese carbonate from a sulfate solution and decomposing the carbonate to oxide.[11]

Recycling.—Scrap recovery specifically for manganese is insignificant. Considerable manganese reenters processing as a minor component of steel scrap, steel slag, and nonferrous scrap.

Economic Factors

As noted in a study of the Minerals Availability Program (MAP) of the U.S Bureau of Mines, transportation is the most significant cost element in the production of manganese concentrates.[12] In a recent MAP assessment of costs for most major mines in MEC's, transportation accounted for about two-thirds of concentrate cost. Transportation costs were about equally divided between transportation to the port and transportation to the market. Also according to this assessment, the major mines for metallurgical-grade ore of the MEC's are quite competitive as to ore production cost. Of the considerable resources evaluated, about 80% had estimated production costs within 20% of the lowest cost.

Operating Factors

Environmental Requirements.—In 1988, the Environmental Protection Agency (EPA) imposed an annual requirement of reporting releases to the environment of manganese chemical compounds and metal (40 CFR 372). This initially applied to operations classifiable within SIC codes 20 to 39 that annually manufacture or process at least 75,000 pounds of these materials, subject to a minimum concentration limitation. This threshold decreased to 25,000 pounds for 1989 and beyond. The threshold for annual use of these materials other than in their manufacturing and processing was 10,000 pounds.

Toxicity.—Manganese is an essential element for people, animals, and plants. In excess, it can be harmful to the respiratory and nervous systems.[13] Thus, manganese can be an industrial poison, but normally is not a hazard.

ANNUAL REVIEW

Legislation and Government Programs

Manganese, including ferromanganese and silicomanganese, was on a revised list of 10 strategic minerals currently imported from the Republic of South Africa that the U.S. Department of State certified to be essential for the economy or defense of the United States and unavailable from reliable and secure suppliers. The revised list was published on January 18 (55 FR 1764) in accordance with section 303(a)(2) of the Comprehensive Anti-Apartheid Act of 1986, as amended. It replaced the prior list of January 7, 1987, that also included manganese.

The U.S. Department of the Interior's Minerals Management Service and the Department of Business and Economic Development of the State of Hawaii jointly released a final environmental impact statement for a proposed marine mineral lease sale that could lead to eventual mining of cobalt-rich manganese crusts in the Pacific Ocean near the Hawaiian Archipelago and Johnston Island. The proposed lease area was in the Exclusive Economic Zone and was estimated to contain significant resources of cobalt, manganese, and nickel. The impact statement analyzed several processing schemes, one of which involved pyrometallurgical recovery of manganese.[14]

Among new regulatory programs affecting manganese materials, the 1990 amendments to the Clean Air Act included manganese compounds among substances to be regulated under the provisions of that act (Public Law 101-549, effective November 15, 1990). The EPA placed manganese and 26 other new substances on a new priority list of candidates for regulation under the Safe Drinking Water Act. The list was effective as of December 31, 1990 (56 FR 1470).

Strategic Considerations

Security of Supply.—Manganese, for which there is no economical substitute, is essential to steelmaking. Steel producers in the MEC's of the United States, Japan, and Western Europe shared a common concern about lack of economically minable domestic manganese deposits. Also, MEC ore supply was from relatively few sources, chiefly Australia, Brazil, Gabon, India, Mexico, and the Republic of South Africa, and from just one or two major ore mining companies in each of these countries. According to one analysis, an index for security of manganese ore supply to such MEC steel producers declined during 1979–87.[15] The United States was additionally concerned about supply of manganese ferroalloys because its domestic ferroalloy industry had declined well below self-sufficiency in manganese.

Stockpile.—The status of goals and inventories of manganese materials in the National Defense Stockpile at the end of 1990 is given in table 2. The only change in goals during 1990 was reduction of that for natural battery ore from 62,000 tons to 25,000 tons, effective late in June. Changes in yearend inventories and sales during 1990 are summarized in table 3. Actual physical changes occurred only for metallurgical ore and high-

TABLE 2

U.S. GOVERNMENT STOCKPILE GOALS AND YEAREND INVENTORIES FOR MANGANESE MATERIALS IN 1990

(Short tons, gross weight)

Material	Stockpile goals	Physical inventory, Dec. 31				
		Uncommitted			Sold, pending shipment	Grand total
		Stockpile grade	Nonstockpile grade	Total		
Natural battery ore	25,000	169,511	33,425	202,936	787	203,723
Synthetic manganese dioxide	25,000	3,011	—	3,011	—	3,011
Chemical ore	170,000	172,655	89	172,744	417	173,161
Metallurgical ore	2,700,000	1,812,039	890,839	2,702,878	15,718	2,718,596
High-carbon ferromanganese	439,000	868,540	—	868,540	—	868,540
Medium-carbon ferromanganese	—	29,072	—	29,072	—	29,072
Silicomanganese	—	23,574	—	23,574	—	23,574
Electrolytic metal	—	14,172	—	14,172	—	14,172

carbon ferromanganese. The changes for chemical ore and medium-carbon ferromanganese resulted from accounting adjustments, which also caused a small adjustment for high-carbon ferromanganese. Most of the change for high-carbon ferromanganese occurred in June when the Defense Logistics Agency accepted into inventory 56,152 tons produced under the stockpile upgrading program. On an overall basis, these changes insignificantly diminished the reserve of approximately 2 million tons of contained manganese being held by the Government.

Issues

The United States has been lacking in reserves and significant production of manganese almost since the start of domestic steel production. Extensive efforts to discover worthwhile ore deposits or effective methods of using low-grade resources, including steel slags, have resulted in little commercial promise. In a 1985 report, the U.S. Congressional Office of Technology Assessment (OTA) concluded that improvements in steel production technology offered the best prospect for reducing U.S. manganese import vulnerability.[16] In so doing, OTA discounted ocean mining for the present, a view shared by most participants at a December 1989 conference on marine mining.[17]

The setting up and maintenance of a large stockpile has been the most tangible aspect of Government manganese programs. Management of this stockpile is a key part of Government policy. Current law limits use of the stockpile to emergency situations, but its mere presence has had economic implications. Questions that have arisen from time to time include what the makeup and size of the manganese stockpile should be and whether it should be used for economic purposes.

Production

Ore and Concentrate.—Production and shipments consisted only of manganiferous material having a natural manganese content of 5% to 15% mined in Cherokee County, SC, for use in coloring brick. Shipments data were not published to avoid disclosing proprietary data. Some use of this manganiferous material to color brick was being displaced by use of ground manganese ore.

Ferroalloys, Metal, and Synthetic Dioxide.—Production statistics for these materials were not published to avoid disclosing proprietary data. Plant sites and products are given in table 4. The production program at the Marietta, OH, plant of Elkem Metals Co., the only producer of manganese ferroalloys, included high-carbon ferromanganese for the Government stockpile and silicomanganese to compensate for shutdowns at other plants of the parent company in Canada and Norway.

Consumption, Uses, and Stocks

Metallurgical applications accounted for most manganese consumption, about 90% for steelmaking. This can be deduced from the data relating to manganese end use in tables 5 and 6 plus certain other information. Table 7 presents industry averages for pounds of manganese used in ironmaking and steelmaking operations per ton of raw steel produced. These 1990 consump-

TABLE 3

SALES AND INVENTORY CHANGES FOR MANGANESE MATERIALS IN U.S. GOVERNMENT STOCKPILE, 1990

(Short tons, gross weight)

Material	Sales		Change in yearend inventory
	Stockpile grade	Nonstockpile grade	
Chemical ore	—	—	+ 938
Metallurgical ore	—	12,320	146,818
High-carbon ferromanganese	—	—	+ 56,383
Medium-carbon ferromanganese	—	—	+ 15

TABLE 4

DOMESTIC PRODUCERS OF MANGANESE PRODUCTS IN 1990

Company	Plant location	Products[1]				Type of process
		FeMn	SiMn	Mn	MnO_2	
Chemetals Inc.	Baltimore, MD	—	—	—	X	Chemical.
Do.	New Johnsonville, TN	—	—	—	X	Electrolytic.
Elkem Metals Co.	Marietta, OH	X	X	X	—	Electric furnace and electrolytic.
Kerr-McGee Chemical Corp.	Hamilton, MS	—	—	X	—	Electrolytic.
Do.	Henderson, NV	—	—	—	X	Do.
Ralston Purina Co.:						
Eveready Battery Co.	Marietta, OH	—	—	—	X	Do.
RAYOVAC Corp.: Materials Div.	Covington, TN	—	—	—	X	Do.

[1] FeMn, ferromanganese; SiMn, silicomanganese; Mn, electrolytic manganese metal; MnO_2, synthetic manganese dioxide.

tion rates, derived from the reported data in tables 5 and 6, were lower for ironmaking but higher for steelmaking than in 1989.

Relatively small quantities of manganese were used for alloying with nonferrous metals, chiefly aluminum. For alloying with aluminum in 1990, the proportion of manganese added as metal was significantly less in relation to that added as manganese-aluminum briquets and other forms than in immediately prior years.

Nonmetallurgical applications for manganese included dry cell batteries, plant fertilizers, animal feed, brick coloring, and manganese chemicals.[18] Two U.S. firms discontinued operations involving manganese in battery production. Bright Star Industries, Clifton, NJ, ended its small production of dry cells, and Eastman Kodak Co. stopped the production of lithium-manganese dioxide batteries that had begun only in 1986 at its Newark, NY, plant.

In addressing environmental concerns associated with dry cell batteries, domestic producers and their foreign affiliates joined in international efforts to minimize mercury usage in such batteries. Mercury contents, used mainly to control hydrogen gassing, were being reduced to zero in carbon-zinc cells (based on natural manganese dioxide) and to 0.025% by weight or less in alkaline cells (based on synthetic manganese dioxide).[19]

Markets and Prices

Manganese Ore.—For the third successive year, the price of metallurgical manganese ore increased significantly and set a new record high for price in commercial transactions. Prices paid by West European and Japanese consumers showed advances in the range of 50% in the face of reported tightness in the supply of high-grade ore and no expansions by major ore producers. The process for setting prices for annual contracts was relatively protracted, extending into August before agreement was reached between South African ore suppliers and Japanese buyers.

The average price, c.i.f. U.S. ports, for metallurgical ore containing 48% manganese was assessed as $3.78 per metric ton unit (mtu), an increase of about 40% over that of $2.76 per mtu in 1989. The mtu is 1% of a metric ton or 22.05 pounds of contained manganese. Dividing the mtu price by 22.05 gives the price per pound of manganese in ore, which was 17.1 cents in 1990 and 12.5 cents in 1989. The price of a metric ton of ore is obtained by multiplying the mtu price by the percentage manganese content of the ore. Mtu pricing has superseded long ton unit (ltu) pricing; in the latter system, the respective 1990 and 1989 prices were $3.84 and $2.80 per ltu.

The ore market consists of a number of submarkets because of differences between ores according to the various end uses such as ferroalloy production, blast furnace ironmaking, and battery manufacture. Table 8 gives the trend for metallurgical ore during the past two decades.

Manganese Ferroalloys.—The general price trend for manganese ferroalloys, as given by quotations for imports, was similar to that in 1989: upward in the first part of the year, then downward and finally some firming of prices near yearend. The increased cost of ore to ferroalloy producers and little change in the rate of raw steel production, at least domestically, appeared to support prices for high-carbon ferromanganese and

TABLE 5

U.S. CONSUMPTION AND INDUSTRY STOCKS OF MANGANESE ORE,[1] BY USE

(Short tons, gross weight)

Use	Consumption		Stocks, Dec. 31	
	1989	1990	1989	1990
Manganese alloys and metal	W	W	W	W
Pig iron and steel	135,000	90,000	167,000	101,000
Dry cells, chemicals, miscellaneous[2]	W	W	W	W
Total	616,000	548,000	518,000	418,000

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1] Containing 35% or more manganese (natural).

[2] Natural ore, including that consumed in making synthetic manganese dioxide.

TABLE 6

U.S. CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF MANGANESE FERROALLOYS AND METAL IN 1990

(Short tons, gross weight)

End use	Ferromanganese			Silico-manganese	Manganese metal
	High carbon	Medium and low carbon	Total		
Steel:					
Carbon	256,022	87,152	343,174	74,121	(1)
Stainless and heat-resisting	13,897	(1)	13,897	5,117	3,101
Full alloy	34,883	8,612	43,495	18,013	725
High-strength, low-alloy	27,364	5,202	32,566	5,969	(1)
Electric	(1)	(1)	(1)	(1)	(1)
Tool	259	3	262	(1)	46
Unspecified	134	639	773	231	1,815
Total steel[2]	332,559	101,608	434,167	103,451	5,687
Cast irons	12,938	1,000	13,938	1,732	—
Superalloys	W	—	W	—	180
Alloys (excluding alloy steels and superalloys)	950	W	950	W	[3]19,047
Miscellaneous and unspecified-	6,067	233	6,300	2,767	510
Total consumption	352,514	102,841	455,355	[4]107,950	25,424
Total manganese content[5]	275,000	82,000	357,000	71,000	25,000
Stocks, Dec. 31:					
Consumers and producers	47,592	13,949	61,541	8,328	3,807

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
[1] Withheld to avoid disclosing company proprietary data; included with "Steel: Unspecified."
[2] Includes estimates.
[3] Approximately 90% of this subtotal was for consumption in aluminum alloys.
[4] Internal evaluation indicates that silicomanganese consumption is considerably understated.
[5] Estimated based on typical percent manganese content (rounded).

TABLE 7

U.S. UNIT CONSUMPTION OF MANGANESE IN IRONMAKING AND STEELMAKING

(Pounds per ton of raw steel unless otherwise specified)

	Form used	1989	1990
	IRONMAKING		
Basis:	Production of raw steel, million tons[1]	97.9	98.9
	Ore[2]	1.2	.8
	STEELMAKING		
Basis:	Production of raw steel and steel castings, million tons	99.1	[e]100.0
	Ore[2]	(3)	(3)
	Ferromanganese	6.7	6.8
	Silicomanganese	1.3	1.4
	Manganese metal	.1	.1
	Total, steelmaking	8.1	8.3

[e] Estimated.
[1] As ingots, continuous- or pressure-cast blooms, billets, slabs, etc.
[2] Containing 35% or more manganese.
[3] None reported.

manganese metal. The year-average price for high-carbon ferromanganese was about 4% higher than that of 1989. Silicomanganese reportedly was in oversupply, so that its year-average price was about 28% lower than that of 1989. Possibly also contributing to a comparative weakness in silicomanganese price was an excess of ferrosilicon, which at least some steel producers could use in combination with ferromanganese in place of silicomanganese.

For high-carbon ferromanganese containing 78% manganese, the price range of imported material, f.o.b. Pittsburgh or Chicago warehouse, began 1990 at $625–$645 per long ton of alloy, which was almost unchanged from that at the end of 1989 and only slightly below the range of $630–$650 at the end of 1990. A peak of $650–$665 was reached in early March.

The price range for imported silicomanganese with 2% carbon, in cents per pound of alloy, f.o.b. Pittsburgh or Chicago warehouse, also showed little net

TABLE 8

TIME-PRICE RELATIONSHIPS FOR MANGANESE IN METALLURGICAL ORE

Year	Average annual U.S. price, dollars per metric ton unit	
	Actual price	Based on constant 1982 dollars
1970	0.53	1.27
1971	.59	1.33
1972	.59	1.27
1973	.64	1.29
1974	.89	1.64
1975	1.36	2.29
1976	1.43	2.26
1977	1.46	2.16
1978	1.38	1.91
1979	1.38	1.75
1980	1.67	1.95
1981	1.69	1.80
1982	1.56	1.56
1983	1.36	1.31
1984	1.40	1.30
1985	1.41	1.27
1986	1.32	1.16
1987	1.27	1.08
1988	1.75	1.44
1989	2.76	2.18
1990	3.78	2.87

movement in 1990, beginning the year at 26–28 and ending at 25.75–26.5. The peak came early in June at 28.25–29.

As given by Metals Week, domestic producer prices (Elkem Metals) for high-carbon ferromanganese and silicomanganese were the same throughout 1990 as at the end of 1989. These prices, f.o.b. plant or warehouse, were $695 for high-carbon ferromanganese and 35 cents for silicomanganese.

Manganese Metal.—For bulk shipments of domestic material, f.o.b. shipping point, trade journals listed a price range of 91–96 or 91–95 cents per pound, the same as at the end of 1989, until mid-November. At that point, citing the high cost of ore, domestic producers raised their price for the balance of the year to $1.04 or $1.05 per pound.

Foreign Trade

Data for exports are summarized in table 9. For ore, unit values again indicated exports to Canada, the majority of exports to countries other than Canada and Mexico, and reexports of 14,243 tons (all to Canada) were metallurgical ore. All reported ore exports to Mexico appeared to have been transshipments of Gabonese ore. Reported exports of spiegeleisen were 855 tons having relatively low unit value, as compared to imports of 187 tons having relatively high unit value.

For all aggregated categories of imports for which data are given in table 10, quantities were less in 1990 than in 1989 except for manganese dioxide. In terms of contained manganese, the decline was less for the sum of ferroalloy plus metal than for the sum of ore plus dioxide; the corresponding ratio, ferroalloy plus metal divided by ore plus dioxide, was the greatest since 1982. Overall imports of ore were the least since 1984 and those of ferromanganese decreased for the third consecutive year. For ore and ferromanganese, average contents returned to values more typical of those in recent years. Content of ore increased to 48.5% and that of ferromanganese to 78.4%.

Among imports of manganese chemicals, all those of dioxide apparently were synthetic dioxide except for 4 tons from Morocco. The quantity of potassium permanganate imported from China rose again to a record amount. Entries for Mexico listed under imports classified as "Other sulfates," which includes manganese sulfate, totaled 11,052 tons valued at $5.1 million.

The schedule of tariffs that applied during 1990 to U.S. imports of selected manganese materials is given in table 11.

World Review

Capacity.—The rated capacity data in table 12 are as of December 31, 1990, and are only slightly changed from those of the previous year. The data correspond to the manganese contents of ore and/or concentrates capable of being utilized, as in feed to a smelter. Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate.

Reserves.—Only a few of the world's many manganese concentrations have enough economic significance to be classed as reserves;[20] no domestic deposits qualify.[21] World reserves of manganese, on the same basis as capacity, are given in table 13 with no distinction between ore type or application. This table excludes perhaps 1% to 2% of total known reserves. These are in nonlisted countries having a similar proportion of world production, as can be seen from table 15.

Australia.—An approximate one-tenth decrease in production of manganese ore by GEMCO was attributed by trade journals partly to the U.S.S.R. not

TABLE 9

U.S. EXPORTS OF MANGANESE ORE, FERROALLOYS, AND METAL, BY COUNTRY

Country	1989		1990	
	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)
ORE AND CONCENTRATES WITH 20% OR MORE MANGANESE				
Canada	16,624	$1,413	20,958	$1,535
Mexico[1]	35,952	2,957	52,641	6,807
Other	4,615	643	3,502	955
Total[2]	57,191	5,014	77,101	9,297
FERROMANGANESE, ALL GRADES				
Belgium	510	490	295	332
Canada	3,108	2,650	5,744	4,302
Chile	1,451	688	15	21
Mexico	1,593	1,240	465	443
United Kingdom	454	405	466	533
Other	[3]1,898	[3]1,838	1,047	932
Total[2]	9,014	7,310	8,032	6,565
SILICOMANGANESE				
Canada	1,590	990	1,141	1,031
Mexico	3,466	2,578	200	145
Trinidad	246	159	389	249
Other	457	342	244	242
Total[2]	5,858	4,068	1,974	1,666
METAL, INCLUDING ALLOYS AND WASTE AND SCRAP				
Canada	1,097	2,422	1,882	5,217
Japan	756	1,194	1,188	2,036
Luxembourg	422	668	983	1,568
Netherlands	1,378	2,609	1,256	2,191
Other	[3]2,012	[3]3,738	1,467	3,031
Total[2]	5,667	10,632	6,773	14,043

[1] Virtually all apparently transshipments from Gabon.
[2] Data may not add to totals shown because of independent rounding.
[3] Unspecified group of countries differs from that in the 1989 Minerals Yearbook.

Source: Bureau of the Census, adjusted by the U.S. Bureau of Mines.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY

Country	1989			1990		
	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)
ORE AND CONCENTRATES WITH 20% OR MORE MANGANESE						
All grades						
Australia	115,844	60,436	$9,492	68,986	35,873	$9,201
Brazil	216,526	r93,283	10,481	51,895	22,776	3,170
Canada[2]	2,173	1,086	49	—	—	—
Gabon[3]	218,039	r109,637	19,196	150,059	74,766	20,928
Ghana	5,692	2,562	148	5,589	2,515	434
Mexico[1]	25,366	9,828	1,425	7,309	3,012	895
Morocco	39	[4]20	9	39	[4]20	11
Norway[2]	—	—	—	25,822	14,242	3,553
South Africa, Republic of	54,821	21,618	2,988	28,504	10,977	1,871
United Kingdom[2]	24	16	5	—	—	—
Total[5]	638,524	298,485	43,794	338,200	164,180	40,054
More than 20% but less than 47% manganese						
Brazil	184,121	77,230	7,700	35,919	15,049	973
Ghana	5,692	2,562	148	5,589	2,515	434
Mexico[1]	24,411	9,369	1,279	7,309	3,012	885
South Africa, Republic of	52,657	20,562	2,776	28,504	10,977	1,871
Total[5]	266,881	109,724	11,903	77,320	31,552	4,164
47% or more manganese						
Australia	115,844	60,436	9,492	68,986	35,873	9,201
Brazil	32,405	r16,053	2,781	15,976	7,727	2,197
Canada[2]	2,173	1,086	49	—	—	—
Gabon[3]	218,039	r109,637	19,196	150,059	74,766	20,928
Mexico	955	r459	146	r—	r—	r—
Morocco	39	[4]20	9	39	[4]20	11
Norway[2]	—	—	—	25,822	14,242	3,553
South Africa, Republic of	2,164	1,056	212	—	—	—
United Kingdom[2]	24	16	5	—	—	—
Total[5]	371,643	188,761	31,891	260,880	132,628	35,890
FERROMANGANESE						
All grades						
Australia	28,987	21,536	8,407	16,295	12,355	5,049
Brazil	15,786	11,980	7,558	26,328	20,167	13,766
Canada	5,139	3,887	1,878	16,102	12,638	7,263
China	8,893	6,787	3,934	10,113	7,909	6,058
France	146,727	115,217	72,988	113,168	89,052	64,147
Germany, Federal Republic of	16,149	13,124	13,643	19,321	16,174	16,501
Mexico	37,775	30,218	28,018	49,472	39,412	31,665
Norway	19,636	16,239	15,730	8,169	6,789	7,103
South Africa, Republic of	181,402	139,267	83,496	144,300	112,015	73,708
Other	15,570	12,228	10,887	15,422	11,839	9,071
Total[5]	476,063	370,483	246,540	418,688	328,352	234,329
1% or less carbon						
France	8,805	7,761	12,552	7,991	7,133	10,945
Italy	r2,083	r1,838	r2,737	836	745	1,140
Norway	5,153	4,402	5,645	2,172	1,801	2,046
Other	r1,134	r1,005	r1,454	1,745	1,532	1,942
Total[5]	17,175	15,006	22,388	12,744	11,212	16,073

See footnotes at end of table.

TABLE 10—Continued

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY

Country	1989			1990		
	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)
			More than 1% to 2% or less carbon			
Brazil	—	—	—	3,638	2,910	$2,778
China	331	265	$226	3,629	2,948	2,762
France	1,378	1,144	1,306	2,800	2,252	2,187
Germany, Federal Republic of	16,133	13,112	13,631	19,306	16,162	16,485
Mexico	34,777	27,987	26,829	27,701	22,307	21,232
Norway	11,386	9,384	8,631	5,997	4,988	5,057
South Africa, Republic of	1,093	867	955	3,069	2,465	2,582
Other	[6]2,204	[6]1,682	[6]1,729	2,755	2,094	2,142
Total[5]	67,302	54,441	53,307	68,895	56,126	55,225
			More than 2% to 4% or less carbon			
Canada	—	—	—	112	88	44
Mexico	73	58	29	—	—	—
Total	73	58	29	112	88	44
			More than 4% carbon			
Australia	28,987	21,536	8,407	16,295	12,355	5,049
Brazil	15,786	11,980	7,558	22,690	17,257	10,988
Canada	5,139	3,887	1,878	15,990	12,550	7,219
China	8,562	6,522	3,708	5,933	4,509	2,940
France	136,544	106,312	59,130	102,377	79,667	51,015
Mexico	2,925	2,173	1,160	21,771	17,105	10,433
South Africa, Republic of	180,309	138,400	82,541	141,231	109,550	71,126
Other	[6]13,261	[6]10,168	[6]6,434	10,650	7,933	4,217
Total[5]	391,513	300,978	170,816	336,937	260,926	162,987
			SILICOMANGANESE			
Argentina	1,149	752	737	12,013	7,901	5,417
Australia	41,281	26,962	16,057	44,815	29,552	19,004
Brazil	24,657	16,147	15,596	24,554	16,059	11,051
France	474	305	375	10,846	7,230	5,318
Mexico	42,854	28,207	24,053	[1]42,691	[1]28,110	[1]19,651
South Africa, Republic of	81,929	52,940	50,948	56,204	37,335	27,664
Yugoslavia	38,715	25,213	25,281	24,493	15,550	11,115
Other	[6]24,332	[6]15,958	[6]18,194	31,823	20,875	18,627
Total[5]	255,391	166,484	151,241	247,439	162,612	117,847
			METAL			
Unwrought:						
China	99	XX	142	280	XX	291
South Africa, Republic of	12,075	XX	16,354	10,073	XX	13,852
Other	—	XX	—	110	XX	265
Total[5]	12,175	XX	16,497	10,463	XX	14,407
Other:						
South Africa, Republic of	3,467	XX	4,388	3,643	XX	4,585
Other	468	XX	1,375	170	XX	746
Total[5]	3,936	XX	5,763	3,815	XX	5,331
Waste and scrap:						
Canada	36	XX	23	1	XX	3

See footnotes at end of table.

TABLE 10—Continued

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY

Country	1989			1990		
	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)	Gross weight (short tons)	Manganese content (short tons)	Value (thousands)
			MANGANESE DIOXIDE			
Belgium	1,284	XX	$1,637	1,200	XX	$1,629
Brazil	1,914	XX	2,045	1,707	XX	2,018
Ireland	377	XX	465	1,349	XX	1,733
South Africa, Republic of	2,651	XX	2,293	3,081	XX	3,862
Other	[r]475	XX	[r]773	349	XX	635
Total[1]	6,701	XX	7,212	7,687	XX	9,877
			POTASSIUM PERMANGANATE			
China	1,038	XX	1,117	1,262	XX	1,182
Germany, Federal Republic of: Eastern states	335	XX	434	[r]382	XX	[r]366
Spain	690	XX	1,274	447	XX	812
Other	136	XX	411	28	XX	216
Total[1]	2,198	XX	3,236	2,119	XX	2,576

[r]Revised. XX Not applicable.
[1]Includes U.S. Bureau of Mines revision of part of reported data.
[2]Country of consignment rather than original source.
[3]Includes quantities believed transshipped to Mexico, about 16,000 tons in 1989 and 51,000 tons in 1990.
[4]Includes U.S. Bureau of Mines conversion of part of reported data (from apparent MnO_2 content to Mn content).
[5]Data may not add to totals shown because of independent rounding.
[6]Unspecified group of countries differs from that in the 1989 Minerals Yearbook.
[7]Includes data listed under the Federal Republic of Germany in Oct.–Dec. 1990.

Source: Bureau of the Census, adjusted by the U.S. Bureau of Mines.

taking all of the shipments for which it had originally contracted. Mine operations at GEMCO, a subsidiary of Broken Hill Pty. Co. Ltd., were at a more normal pace as compared with 7-day, 3-shift schedules worked in 1989.

A 50–50 joint venture between Pilbara Port Railway Resources, a wholly owned subsidiary of Hancock Mining Ltd., and Portman Mining Ltd., partly owned by Pennant Resources Ltd., re-established manganese ore production in the Woodie Woodie area of the east Pilbara region in Western Australia. Surface mining to yield 275,000 tons per year of product was projected for at least 5 years. The two main products of the operation, both low in phosphorus, were a siliceous ore containing about 43% manganese and a higher grade ore with 46% to 47% manganese. Transportation was by road trains over a distance of about 240 miles to ocean shipping at Port Hedland. Initial customers for the ore were in the Far East, with shipments beginning late in 1990 to China, the Republic of Korea, and Taiwan.

TABLE 11

U.S. IMPORT DUTIES ON MANGANESE MATERIALS[1]

Item	HTS No.	Rate of duty effective Jan. 1, 1990	
		Most favored nation (MFN)	Non-MFN
Manganese dioxide	2820.10.00	4.7% ad valorem[2 3 4]	25% ad valorem.
Ore and concentrate	2602.00.00	Free	1 cent per pound Mn.
Ferromanganese:			
Low-carbon	7202.19.10	2.3% ad valorem[2 3 5]	22% ad valorem.
Medium-carbon, 1% to 2% carbon	7202.19.50	1.4% ad valorem[2 3 5 6]	6.5% ad valorem.
High-carbon	7202.11.50	1.5% ad valorem[2 5]	10.5% ad valorem.
Silicomanganese	7202.30.00	3.9% ad valorem[2 3 5 7]	23% ad valorem.
Metal	8111.00.45	14% ad valorem[2 8]	20% ad valorem.

[1]All subject to (1) 0.17% ad valorem user fee except for products from beneficiary countries under the Caribbean Basin Economic Recovery Act (CBERA) and least developed developing countries and (2) 0.04% ad valorem harbor maintenance fee for cargo unloaded from waterborne vessels at U.S. ports open to public navigation.
[2]Free if from beneficiary countries under CBERA and for products of Israel.
[3]Free ... for certain countries under Generalized System of Preferences.
[4]2.8% ad valorem for products of Canada.
[5]Free for products of Canada.
[6]Not duty free for Mexico.
[7]Not duty free for Brazil.
[8]11.2% ad valorem for products of Canada.

Brazil.—Shipments of manganese ores from the Serra do Navio, Amapá Territory, operations of ICOMI, a subsidiary of Cia. Auxiliar de Empresas de Mineração S.A. (Caemi), decreased 16% overall to 617,000 tons. Shipments, via Porto de Santana on the Amazon River, declined only moderately for exports to 529,000 tons, but dropped by about one-half, to 88,000 tons, for those to Brazilian consumers. About three-fifths of total shipments consisted of low-grade and

TABLE 12

WORLD ANNUAL MANGANESE MINE PRODUCTION CAPACITY, DECEMBER 31, 1990

(Thousand short tons of manganese content)

	Rated capacity
North America:	
Mexico	230
United States	—
Total	230
South America:	
Brazil	1,100
Chile	20
Total	1,120
Europe:	
Bulgaria	15
Hungary	30
U.S.S.R.	3,300
Other	40
Total	3,385
Africa:	
Gabon	1,350
Ghana	150
Morocco	30
South Africa, Republic of	2,300
Total	3,830
Asia:	
China	600
India	600
Other	15
Total	1,215
Oceania:	
Australia	1,250
World total (rounded)	11,000

carbonate ores.

Caemi expanded its manganese operations in Amapá Territory by inaugurating production of ferromanganese in the second half of the year at Cia. Ferroligas do Amapá (CFA), a recently formed subsidiary. Like a sinter plant completed by ICOMI in 1989, CFA's one-furnace ferroalloy plant was in the Porto de Santana area. ICOMI was the source of a mix of medium-grade metallurgical ore, carbonate ore, and sinter being fed to CFA's 12.4-megawatt-ampere furnace, rated for ferromanganese at 25,000 tons per year. Output of sinter during 1990 was about 80,000 tons.

Total manganese ore shipments from the Azul Mine of CVRD in the Carajás region declined by about one-fifth to 477,000 tons. Shipments to Brazilian consumers rose to 219,000 tons, but exports decreased by more than one-third to 258,000 tons.[22] Urucum Mineração S.A., about 47% owned by CVRD, was engaged in fulfilling a multiyear agreement to supply ore to Romania from its operations near the Bolivian border in the State of Mato Grosso do Sul.

Production of manganese ferroalloys declined just slightly from 1989's record-high total to 427,000 tons. With approximately the same output of high-carbon ferromanganese, a small increase in production of silicomanganese to a new record of 239,000 tons counterbalanced a one-third decrease in production of medium- and low-carbon ferromanganese to 19,000 tons. Investment in manganese ferroalloy facilities reportedly was adversely affected by Federal and State economic and tax programs.

Production of electrolytic manganese metal was initiated early in 1990 by the Metalman S.A. subsidiary of Metalur Ltda. at its plant near São Luís, Maranhão State. However, plant output did not progress to the 13,000-ton-per-year level projected for the latter part of 1990. CVRD was supplying ore to Metalman from its Azul Mine nearby.

Bulgaria.—Four state-owned Bulgarian companies entered into an agreement with Norway's Elkem under which Elkem was to be furnished with about 28,000 tons per year of manganese ore and in turn supply Bulgaria with ferromanganese and technology. The agreement, valued at more than $150 million, extended for 5 to 7 years and stipulated that Bulgaria would not restart ferromanganese production, which had ended late in 1989. Bulgarian companies involved were Kremikovtzi, Mangan, Metalsnab, and Rudmetal, the latter a trading company. The Obrochishte Mine near Varna on the Black Sea Coast in eastern Bulgaria presumably would be the ore source.

Canada.—In the latter part of the year, a test lot of a 45% manganese lump product was shipped by Hollinger North Shore Exploration Inc., a subsidiary of La Fosse Platinum Group Inc. Operations being conducted near Schefferville in northeastern Quebec adjacent the Labrador border included initial startup of a heavy-medium ore-beneficiating plant. Progression into commercial production of several manganese ore products at a total annual rate approaching 300,000 tons was projected within 5 years. Mining was to be by surface methods and confined to the mid-May to mid-October warmer season.

Gabon.—Capacity for ore production and actual ore output of COMILOG remained well below shipping capabilities provided by the dual routes of the new rail-to-port system within Gabon and the original aerial tramway-to-rail-to-port system terminating at Pointe-Noire in neighboring Congo. Transport of ore at the Moanda Mine was now benefiting from two conveyor systems, one for moving ore from the truck receiving point within the mine to the washing plant and another for carrying ore from the mine stockyard to the railhead of the Trans-Gabon Railroad. Production of 2,858,000 tons of ore in 1989, the highest annual total to that point, included 101,000 tons of battery-grade ore.

Ghana.—A total of 281,000 tons of ore was exported from the Nsuta Mine of Ghana National Manganese Corp.

TABLE 13

WORLD MANGANESE RESERVES AND RESERVE BASE

(Million short tons of manganese content)

	Reserves	Reserve base
North America: Mexico	4	10
South America: Brazil	23	63
Europe: U.S.S.R.	325	500
Africa:		
Gabon	58	180
Ghana	1	5
South Africa, Republic of	407	2,900
Total	466	3,085
Asia:		
China	15	32
India	19	28
Total	34	60
Oceania: Australia	44	170
World total (rounded)	900	3,900

through the Port of Takoradi compared with 314,000 tons exported in 1989. Shipments were made to Japan, the United States, and, in Europe, to Finland, Greece, Ireland, the Netherlands, Norway, Romania, and Spain.[23] Shipments in 1990 descended to a level just 4% below that of the annual average for 1984–89.

India.—The Government recentralized manganese ore exports through the State-owned Minerals and Metals Trading Corp. and raised to 550,000 tons the quantity of ore that could be exported during the 1990 fiscal year beginning April 1. This followed a brief period beginning during the latter part of the 1989 fiscal year when such exports were decentralized. Ore exports during the 1989 fiscal year had been limited to 440,000 tons of low- and medium-grade ore, with exports of high-grade ore permitted only on a selective basis and provided the ore had a relatively high phosphorus content of more than 0.18%.

Japan.—The slightly increased total of 584,000 tons for production of manganese ferroalloys was the greatest since 1985. Ferromanganese output rose 15% to 499,000 tons, the highest level since 1984. Production of silicomanganese was adversely affected by mishaps affecting two large units and fell 37% to 85,000 tons.

Foreign trade in manganese ferroalloys was diminished from that in 1989, except that imports of ferromanganese approximately doubled to 48,000 tons. Imports of silicomanganese decreased 39% to 215,000 tons, of which China supplied more than 40%. Exports declined about 60% for both ferromanganese, to 6,200 tons, and silicomanganese, to 1,200 tons.

In synthetic dioxide, production of EMD decreased more than 7% to 56,700 tons, again the least since 1985. Exports of EMD decreased further to 33,200 tons, the least since 1981. In October, Daiichi Carbon Co. Ltd. ended production of EMD, partly because of waste disposal problems. With an annual capacity of about 3,000 tons, Daiichi Carbon had been Japan's smallest EMD producer. At about the same time, Chuo Denki Kogyo Co. began commercial production of a high-grade chemical manganese dioxide (CMD-U) intended to compete with EMD in battery applications. This was at the company's Taguchi plant in Niigata Prefecture, about 100 miles northwest of Tokyo. The plant was designed on the basis of research and development involving cooperation between Toshiba Battery Co. and Sumitomo Metal Industries Ltd. and had an annual capacity for CMD-U of 6,600 tons.

Production of electrolytic manganese metal was up slightly to 5,040 tons. Imports of unwrought manganese metal, including scrap, rose by more than one-fourth to 15,100 tons, of which more than 60% was from the Republic of South Africa and approximately one-third was from China.

Mexico.—Operations of Autlán in the Molango District of Hidalgo State were the principal source of manganese ore products. Autlán's production for 1990 and 1989, respectively, were, in tons, 737,000 and 700,000 for carbonate ore, 368,000 and 388,000 for oxide nodules produced by calcining carbonate ore, and 23,900 and 19,700 for battery ore from the Nonoalco Mine.

Following a 2-year development program, Ferroaleaciones de México, S.A. added medium-carbon ferromanganese to high-carbon ferromanganese and silicomanganese as regular products of its plant at Gómez Palacio, Durango State. Using a 13-ton converter, the company worked out practices giving 91% manganese recovery in oxygen decarburization of high-carbon ferromanganese.[24]

South Africa, Republic of.—Total ore production advanced slightly, rising for the third consecutive year. Production in 1990 of the various categories of ore was as given in table 14.

Manganese ore shipments by AMMOSAL decreased more than one-fourth to 1,445,000 tons.

South African ore producers were looking to expand both their marketing to Eastern Europe and capability for producing high-grade ore from key underground mines in the Cape Province's Kalahari Field. AMMOSAL was studying the feasibility of sinking a new vertical shaft that would increase capacity of its N'Chwaning Mine significantly. Samancor progressed with development work aimed at expanding production from the western block of its Wessels Mine. Ore depletion caused Samancor's Hotazel surface mine to be closed as of the end of June.

TABLE 14

SOUTH AFRICAN MANGANESE ORE PRODUCTION, 1990

Grade	Quantity (thousand short tons, gross weight)[1]
METALLURGICAL ORE	
30% to 40% Mn	1,100
Over 40% to 45% Mn	800
Over 45% to 48% Mn	569
Over 48% Mn	1,487
Total	3,956
CHEMICAL ORE	
35% MnO_2 and less	10
Over 35% to 65% MnO_2	76
Over 65% to 75% MnO_2	6
Total	92

[1]Data may not add to totals shown because of independent rounding.

Production capacities for silicomanganese and ferromanganese were increased by about 50,000 tons each. In February, the Transalloys Div. of Highveld Steel & Vanadium Corp. Ltd. commissioned a fifth silicomanganese furnace at its works at Witbank in Transvaal Province. In the latter half of 1990, the Feralloys Ltd. subsidiary of AMMOSAL added a ferromanganese furnace at its plant at Cato Ridge, Natal Province. AMMOSAL also then shut down three smaller furnaces indefinitely.

U.S.S.R.—Reports in trade journals indicated the quantity of manganese ore imported by the U.S.S.R. from such principal current sources as Australia and Gabon was much reduced. Receipts may not have exceeded one-half the quantities contracted for because of a shortage of hard currency on the part of the U.S.S.R.

The U.S.S.R.'s production of potassium permanganate was ended in the first part of the year when the country's facilities for producing this chemical were closed because of problems with waste disposal. These facilities, in the Crimean Black Sea city of Saki, had an annual capacity of about 6,000 tons. Because of their closure, an antidumping duty imposed in June by the Commission of the European Commu-

nity (EC) on imports of potassium permanganate from the U.S.S.R. was only provisional. This action had joined the U.S.S.R. with other permanganate producers in Eastern Europe and China against which the EC had established antidumping controls.

Ore exports of 987,000 tons in 1989 were 9% less than those in 1988, with those to Poland decreasing 22% and those to Czechoslovakia increasing 42%. Destinations for 1989 exports were, in tons, Poland, 506,000; Czechoslovakia, 280,000; German Democratic Republic, 90,000; North Korea, 32,000; Yugoslavia, 29,000; Bulgaria, 12,000; and unspecified, 38,000.

Current Research

Methods of economically utilizing low-grade domestic manganese resources continued to be investigated. In the United States, the U.S. Bureau of Mines explored use of calcium fluoride to facilitate sulfuric acid leaching of manganese silicate minerals. Tests in which manganese extractions of more than 90% were achieved were conducted on material typifying pyroxmangite ores of the Sunnyside district of San Juan County, CO.[25] The manganese content was about 34%. In Italy, laboratory studies were conducted to determine the best conditions for solubilizing manganese from manganese dioxide-type ore by percolation leaching with aqueous sulfur dioxide and by bioleaching. For either approach, up to 20 days was required to achieve high extraction of manganese. The ore samples were from central western Italy and contained about 18% manganese.[26]

Geological investigation indicated a correlation between development of an economic manganese deposit and the existence of certain oxygen-poor, sulfur-rich conditions of the marine environment during deposition. This conclusion was reached from examination of organic carbon and sulfide sulfur contents of manganese ores and their host

TABLE 15

MANGANESE ORE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand short tons)

Country[2]	Range percent Mn[e, 3]	Gross weight					Metal content				
		1986	1987	1988	1989	1990[e]	1986	1987	1988	1989	1990[e]
Australia[4]	37–53	1,818	2,043	2,189	2,341	r2,191	867	972	r1,041	1,111	r1,009
Brazil[6, 7]	30–50	2,973	2,279	2,194	2,293	2,200	1,277	842	r841	r871	840
Bulgaria	29	41	42	r39	r e67	72	12	12	r11	r e19	20
Chile	30–40	35	35	48	48	r44	12	12	16	15	r16
China[6, 8]	20–30	3,000	r2,900	r3,500	r e3,500	3,500	600	r580	r700	r700	700
Gabon[6, 9]	50–53	2,767	2,649	2,485	r2,858	2,900	1,277	1,223	1,147	r1,319	1,340
Ghana[6]	30–50	335	303	286	r308	280	122	108	106	r121	110
Hungary[6, 10]	30–33	69	86	89	r93	94	21	28	29	r29	29
India[6, 9, 11]	10–54	1,337	1,435	r1,469	r1,471	1,500	498	534	r547	r548	560
Iran[6]	25–35	r37	r33	r34	r39	39	r11	r10	r10	r12	12
Mexico[12]	27–50	r506	r425	r489	r e435	447	192	161	186	r165	170
Morocco[6]	50–53	44	47	33	r35	35	24	25	18	r19	19
Romania[6, 10]	30	74	r72	r72	r66	60	22	21	21	20	19
South Africa, Republic of[6, 9]	30–48 +	4,100	3,188	3,807	3,994	r4,048	1,663	1,337	1,571	1,675	1,710
U.S.S.R.	29–30	10,300	10,400	10,000	r e10,000	9,700	3,100	3,100	r3,000	r e3,000	2,900
Yugoslavia	25–45	46	46	44	r43	44	16	16	r15	15	15
Other[e, 13]	XX	r40	r25	r39	r36	37	r16	r10	r17	r16	17
Total[14]	XX	r27,523	r26,006	r26,817	r27,626	27,192	r9,730	r8,991	r9,276	r9,655	9,486

e Estimated. r Revised. XX Not applicable.

[1] Table includes data available through May 17, 1991. Data pertain to concentrates or comparable shipping product, except that in a few instances the best data available appear to be for crude ore, possibly after some upgrading.

[2] In addition to the countries listed, Colombia, Cuba, Panama, Peru, and Sudan may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels. Low-grade ore not included in this table has been reported as follows, in thousand short tons, gross weight: Argentina (19% to 30% Mn), 1986—11, 1987—r, e (revised), 1988—10 (revised), 1989—7, and 1990—6 (estimated); and Czechoslovakia (about 17% Mn), an estimated 1 in each year.

[3] May be for average content of each year's production rather than for content of typical products.

[4] Metallurgical ore.

[5] Reported figure.

[6] Gross weight reported; metal content estimated. Estimated metal content figures have been revised as necessary.

[7] Reported gross weight figures are the sum of (1) sales of direct-shipping manganese ore and (2) production of beneficiated ore; both as reported in Anuário Mineral Brasileiro.

[8] Includes manganiferous ore.

[9] Calculated metal content includes allowance for assumed moisture content.

[10] Concentrate.

[11] Much of India's production grades below 35% Mn; average content was reported as 38% Mn in 1985.

[12] Estimated product total, mostly oxide nodules; may include smaller quantities of direct-shipping carbonate and oxide ores for metallurgical and battery applications.

[13] Category represents the combined totals of Greece, Indonesia, Italy (from wastes), Japan, the Republic of Korea, Pakistan, the Philippines, Thailand, Turkey, and Zambia.

[14] Data may not add to totals shown because of independent rounding.

rocks for deposits in China, Mexico, and Newfoundland.[27]

Steels are tending to be produced with progressively lower contents of residual elements. Increased emphasis on making steels with a phosphorus specification of 0.02% or less has implications for manganese-bearing materials used in ironmaking. One method for controlling phosphorus content of steels is to be selective in using low-phosphorus manganese ores in blast furnace feed.[28] Another approach for minimizing steel phosphorus content is to eliminate recycling of steelmaking slag to the blast furnace.[29]

In electric furnace steelmaking, technology is being developed for stirring the bath by injecting gases through the furnace bottom. Metallurgical improvements attained include increased manganese yield, as in the Federal Republic of Germany at Thyssen Stahl, where stirring was done with nitrogen followed by argon.[30] An electric furnace steelplant in Mexico raised manganese yield by 40% by stirring with natural gas.[31]

Manganese has been used in stainless steel as a substitute for nickel in times of nickel shortage. The thesis was advanced recently that, to avoid letting the economics of nickel supply limit future growth of the stainless steel market, nickel supply could be extended by using manganese and nitrogen in such steels.[32] The super collider to be built by the U.S. Department of Energy is a potential user of manganese-nitrogen stainless steel.[33]

The equilibrium diagram of the manganese-nitrogen system at temperatures up to 1,400° C was reviewed by the U.S. Bureau of Mines. The thermodynamics and crystal structure of the solid and liquid phases within this system were described.[34]

In the plant world, research into the complexities of photosynthesis has revealed aspects of the key role of manganese in enabling cells to derive their energy by dissociating water molecules. Manganese assists this aerobic process, which liberates life-giving oxygen as a byproduct, through the ability of manganese to exist in different oxidation states.[35]

OUTLOOK

The trend of manganese demand, domestically and globally, will continue to closely follow that of steel production. Nonmetallurgical components of manganese demand, especially batteries, may experience higher growth rates

TABLE 16

MANGANESE SUPPLY-DEMAND RELATIONSHIPS[1]

(Thousand short tons, manganese content)

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
Domestic mines[2]	31	23	24	4	4	11	2	1	2	1	1
Shipments of Government stockpile excesses	264	159	128	28	35	10	91	8	105	−2	−6
Imports, ore and dioxide[3]	244	330	301	111	178	180	204	237	181	262	303
Imports, ferroalloy and metal	708	530	615	430	364	426	405	452	422	581	553
Industry stocks, Jan. 1	811	749	710	702	576	463	420	380	315	279	316
Total U.S. supply	2,058	1,791	1,778	1,275	1,157	1,090	1,122	1,078	1,025	1,121	1,167
Distribution of U.S. supply:											
Industry stocks, Dec. 31	749	710	702	576	462	420	380	315	279	316	324
Exports, ore	29	26	32	14	10	30	31	23	38	35	29
Exports, ferroalloy and metal	30	26	17	13	17	13	13	10	9	18	17
Industrial demand	1,250	1,029	1,027	672	668	627	698	730	699	752	797
U.S. DEMAND PATTERN[3]											
Appliances and equipment	59	49	51	30	33	36	32	27	31	19	12
Batteries	17	17	16	21	25	34	39	43	43	48	45
Cans and containers	61	49	46	31	28	38	35	31	35	31	23
Chemicals[4]	59	50	50	29	22	34	22	23	44	46	43
Construction	291	243	252	152	151	170	164	148	165	244	152
Machinery	217	167	171	92	90	97	78	65	77	110	83
Oil and gas industries	70	79	89	40	28	36	34	25	30	21	10
Transportation	296	214	214	115	129	139	124	95	105	102	54
Other[5]	180	161	138	162	162	43	170	273	169	131	375
Total U.S. primary demand	1,250	1,029	1,027	672	668	627	698	730	699	752	797

[1] Where available, data for manganese dioxide included beginning in 1984.
[2] Including manganiferous ore.
[3] New series for steel-related end uses beginning in 1989.
[4] Includes miscellaneous nonmetallurgical uses of ore beginning in 1987.
[5] Not specifically based on reported data; includes processing losses. Through 1988, the distribution within this category is approximately the same as for end uses above. Beginning in 1989, includes nonidentified uses of steel corresponding to about one-third of total steel shipments.

than for steel production, but will have only a minor effect on overall manganese demand.

U.S. apparent consumption of manganese has been in the range of approximately 700,000 to 800,000 tons of contained manganese during 1985–89, as given in table 16. How this measure of domestic demand will vary on a year-to-year basis in 1991–95 is affected by uncertainties in the outlook for domestic steel production, as discussed in the annual report for "Iron and Steel." Particular uncertainty is associated with effects related to foreign trade, in which trends are sensitive to Government policy and currency exchange rates. Forecasts such as those of the International Iron and Steel Institute (IISI) generally indicate little growth in U.S. steel output through 1995. The range for U.S. apparent consumption of manganese in 1991–95 could well be much the same as that during the preceding 5 years, assuming no significant changes in manganese unit consumption in steelmaking. The majority of U.S. demand will be met by imports.

Global forecasts of IISI and others suggest that the average annual growth rate for world manganese demand in 1991–95 should be close to 1%. Evolving political and economic developments could have a significant impact on traditional manganese supply-demand relationships in the near future. A significant potential appears to exist for a decline in the U.S.S.R.'s ore production and exports, 90% or more of which have been to Eastern Europe since at least 1978.

[1] Mining Magazine. Manganese. V. 162, No. 1, Jan. 1990, pp. 36–40.

[2] McMichael, B. Manganese: EMD—The Power in the Market. Ind. Miner. (London), No. 260, May 1989, pp. 42–59.

[3] Unless otherwise specified, the unit of weight in this report is the short ton of 2,000 pounds.

[4] Carter, L. J. Electrolytic Manganese—A Long Term Industry. Metal Bull. Monthly, No. 175, July 1985, pp. 21, 23.

[5] Glover, D., B. Schumm, Jr., and A. Kozawa (eds.). Handbook of Manganese Dioxides, Battery Grade. Intl. Battery Mater. Assoc., Cleveland, OH, 1989, 341 pp.

[6] DeYoung, J. H., Jr., D. M. Sutphin, and W. F. Cannon. International Strategic Minerals Inventory Summary Report—Manganese. U.S. Geol. Surv. Circ. 930–A, 1984, 22 pp.

Force, E. R., and W. F. Cannon. Depositional Model for Shallow-Marine Manganese Deposits Around Black Shale Basins. Econ. Geol., v. 83, 1988, pp. 93–117.

[7] Dancoisne, P. L. World Situation of Manganese Resources and Reserves. Materials and Society, v. 9, No. 3, 1985, pp. 353–369.

[8] Machamer, J. R. A Working Classification of Manganese Deposits. Min. Mag., v. 175, No. 4, Oct. 1987, pp. 348–351.

[9] Matricardi, L. R., and J. H. Downing. Manganese and Manganese Alloys. Ch. in Kirk-Othmer Encyclopedia of Chemical Technology. Wiley, v. 14, 3d ed., 1981, pp. 824–843.

Wellbeloved, D. B., P. M. Craven, and J. W. Waudby. Manganese and Manganese Alloys. Ch. in Ullmann's Encyclopedia of Industrial Chemistry. VCH Publishers, New York, v. A16, 5th ed., 1990, pp. 77–121.

[10] Deane, M. E. Electrolytic Manganese Dioxide Production in Ireland. Trans. Inst. Min. and Metall., Sec. A, v. 94, July 1985, pp. A169–A172.

[11] Reidies, A. H. Manganese Compounds. Ch. in Ullmann's Encyclopedia of Industrial Chemistry. VCH Publishers, New York, v. A16, 5th ed., 1990, pp. 123–143.

[12] Coffman, J. S., and C. M. Palencia. Manganese Availability—Market Economy Countries. BuMines IC 8978, 1984, 26 pp.

[13] U.S. Environmental Protection Agency. Health Assessment Document for Manganese. EPA-600/8-83-013F, Aug. 1984.

[14] U.S. Minerals Management Service and the State of Hawaii Department of Business and Economic Development, Ocean Resources Branch (Honolulu). Proposed Marine Mineral Lease Sale: Exclusive Economic Zone Adjacent to Hawaii and Johnston Island. Final Environmental Impact Statement. Aug. 1990, v. 1, 503 pp.; v. 2, Appendices A through J.

[15] Harker, R. I., and T. M. Lutz. Securities of Mineral Supplies. Resources Policy, v. 16, No. 2, June 1990, pp. 115–127.

[16] U.S. Congressional Office of Technology Assessment. Strategic Materials: Technologies To Reduce U.S. Import Vulnerability. OTA-ITE-248, May 1985, 409 pp.

[17] Johnson, C. J., and A. L. Clark. Introduction. Paper in Proceedings of the Conference on Marine Mining Technology for the Twenty-First Century (Honolulu, HI, Dec. 4–6, 1989). Materials and Society, v. 14, No. 3/4, 1990, pp. 205–208.

[18] Weiss, S. A. Manganese—The Other Uses. Met. Bull. Books, Ltd., London, England, 1977. 360 pp.

[19] Spahrbier, D. Mercury Reduction Programme for Primary Batteries. Chem. & Ind. (London), No. 13, July 2, 1990, pp. 431–435.

[20] National Materials Advisory Board. Manganese Reserves and Resources of the World and Their Industrial Implications. Natl. Acad. Sci., Washington, DC, NMAB-374, 1981, 334 pp.

[21] Kilgore, C. C., and P. R. Thomas. Manganese Availability—Domestic. BuMines IC 8889, 1982, 14 pp.

[22] Skillings' Mining Review. V. 80, No. 12, Mar. 23, 1991, p. 17.

[23] ———. V. 80, No. 17, Apr. 27, 1991, p. 21.

[24] Montoya, A., and A. Sevilla. Refining of Manganese Alloys by Bottom Blowing. Paper in Proceedings of the 48th Electric Furnace Conference (New Orleans, LA, Dec. 11–14, 1990). AIME, Warrendale, PA, 1991, pp. 233–239.

[25] Droes, S. R., K. P. V. Lei, and T. G. Carnahan. Leaching of Pyroxmangite Ore With Calcium Fluoride and Sulfuric Acid. BuMines RI 9318, 1990, 8 pp.

[26] Abbruzzese, C., M. Y. Duarte, B. Paponetti, and L. Toro. Biological and Chemical Processing of Low-Grade Manganese Ores. Miner. Eng., v. 3, No. 3/4, 1990, pp. 307–318.

[27] Liu, T. C-S. Relationships in Shales Hosting Manganese Ores From Mexico, China, and Newfoundland: Implications for Depositional Environment and Mineralization. Ore Geol. Revs., v. 5, No. 4, May 1990, pp. 325–340.

[28] Kokal, H. R. The Origin of Phosphorus in Iron-making Raw Materials and Methods of Removal—A Review. Paper in Proceedings of Minnesota Section AIME 63d Annual Meeting and University of Minnesota 51st Annual Mining Symposium. MN Sec. AIME, 1990, pp. 225–257.

[29] Bloom, T. A., D. R. Fosnacht, and D. M. Haezebrouck. The Influence of Phosphorus on the Properties of Sheet Steel Products and Methods Used to Control Steel Phosphorus Levels in Steel Product Manufacturing. Iron & Steelmaker, v. 17, 1990, pt. 1, No. 9, pp. 35–41; pt. 2, No. 10, pp. 59–62.

[30] Bachmayer, J., E. Hoffken, F. J. Strunck, and J. Wolf. Bottom Stirring With the Thyssen Long-Time Stirrer at the Oberhausen EAF Shop of Thyssen Stahl AG. Iron & Steelmaker, v. 18, No. 2, Feb. 1991, pp. 22–26.

[31] Lazcano, A., and G. Vargas. Startup and Preliminary Results of Bottom Blowing Natural Gas Into an EBT Arc Furnace at DEACERO, S.A. Iron & Steelmaker, v. 17, No. 5, May 1990, pp. 58–62.

[32] Wellbeloved, D., and J. Stanko. Manganese—a Substitute for Nickel? Metal Bull. Monthly, Jan. 1990, pp. 61–63.

[33] Hess, G. Super Collider's Steel Needs Won't Be Run of the Mill. Iron Age, v. 6, No. 12, Dec. 1990, pp. 27–28.

[34] Gokcen, N. A. The Mn-N (Manganese-Nitrogen) System. Bull. Alloy Phase Diagrams, v. 11, No. 1, 1990, pp. 33–42.

[35] Govindjee, and W. J. Coleman. How Plants Make Oxygen. Sci. American, v. 262, No. 2, Feb. 1990, pp. 50–58.

OTHER SOURCES OF INFORMATION

Bureau of Mines Publications

Manganese. Ch. in Minerals Yearbook, annual.

Manganese. Ch. in Mineral Commodity Summaries, annual.

Manganese. Monthly and preliminary annual Mineral Industry Surveys.

Minerals Today. A bimonthly publication.

Other Sources

American Metal Market (daily paper).

Company annual reports.

Engineering and Mining Journal.

Industrial Minerals (London).

Metal Bulletin (London).

Metals Week.

Mining Journal (London).

Mining Magazine (London).

Proceedings of ferroalloy conferences (INFACON, etc.).

Roskill Information Services Ltd. (London; last reported on manganese in 1989).

Skillings' Mining Review.

TEX Report (Tokyo; daily issues and annual ferroalloy manual)

☆ U.S. Government Printing Office : 1991 - 281-983/40079